

71-13018

NASA CR 111523

F-70-50116

**CASE FILE
COPY**

LASER SYSTEM OF EXTENDED RANGE

Progress Report No. 2

For the period 1 May 1970 through 31 July 1970

Contract NASW-2014

August 1970

Prepared for

National Aeronautics and Space Administration
Washington, D.C. 20546

Smithsonian Institution
Astrophysical Observatory
Cambridge, Massachusetts 02138

LASER SYSTEM OF EXTENDED RANGE

Progress Report No. 2

For the period 1 May 1970 through 31 July 1970

Contract NASW-2014

August 1970

Prepared for

National Aeronautics and Space Administration
Washington, D.C. 20546

Smithsonian Institution
Astrophysical Observatory
Cambridge, Massachusetts 02138

TABLE OF CONTENTS

<u>Section</u>		<u>Page</u>
1	INTRODUCTION.	1
2	PROGRAM OBJECTIVE.	2
3	PROGRAM PLAN.	3
4	TASKS SUPPORTED BY CONTRACT NASW-2014.	4
5	PROGRESS ON TASKS SUPPORTED BY CONTRACT NASW-2014.	5
6	DESCRIPTION OF THE TEMPORARY LASER SYSTEM.	6
7	ANALYSIS.	10

LASER SYSTEM OF EXTENDED RANGE

Progress Report No. 2

1. INTRODUCTION

This progress report is concerned with the extended-range laser program of the Smithsonian Astrophysical Observatory (SAO). Although there are references to the overall objectives of the program, the progress reported concerns the subject contract only.

2. PROGRAM OBJECTIVE

The overall program objective is the development of a prototype laser system that will range to geosynchronous satellites and beyond. When ranging to the moon, returns as strong as those received by the lunar-laser systems of NASA and AFCRL are expected.

The repetition rate of the high-radiance, neodymium-glass laser used in this program is lower than that of a ruby laser. However, the glass laser has a much lower beam divergence, which makes it possible to achieve a given beamwidth with a transmitting telescope having a diameter an order of magnitude smaller than that required for a ruby laser. This is what makes a transportable transmitting unit possible. When ranging to geosynchronous satellites, the transmitting unit with minor modifications can also perform the receiving function. Therefore, the complete system is independent and can be easily transported. For lunar ranging the transmitter can be located at any observatory where a telescope 60 inches or larger is available. The large telescope is used only for the reception of the laser return. The only required modifications to the large telescope are the addition of a photometric package and, if not already available, a provision for offset guiding.

3. PROGRAM PLAN

The program objective is being accomplished in the following three steps:

A. The procurement, installation, and operation of a temporary system at Agassiz Observatory, Harvard, Massachusetts. This system will use a neodymium-glass laser to range to near-earth satellites. It will test the neodymium-glass laser and the coudé pointing system under field conditions. The temporary system will consist of the following components:

1. A neodymium-glass laser (rented).
2. Temporary transmitting optics.
3. Temporary photoreceiver.
4. Ranging electronics (near-earth).
5. Shelter for the above components.

B. The laser from step 1 will become the prototype system at Agassiz with the following additions:

1. An extended-range transmitter (ERT).
2. Modification of the 61-inch telescope at Agassiz for use as a photoreceiver.
3. Modification of the ranging electronics for extended ranging.

This prototype system will be operated at Agassiz to demonstrate its abilities for lunar ranging.

C. The prototype system will then be moved to Mt. Hopkins, where lunar ranging operations will begin. The system will also be used to obtain accurate range measurements to ATS-F and -G, and any other high-altitude satellites that are equipped with retroreflectors. This step will require the building of a shelter and modification of the 60-inch telescope for use as a photoreceiver.

4. TASKS SUPPORTED BY CONTRACT NASW-2014

During this reporting period, Contract NASW-2014 supported the following tasks at SAO:

- A. Arrange for the rental of a neodymium-glass laser from American Optical Corporation, Southbridge, Massachusetts.
- B. Design and fabricate appropriate temporary transmitting optics.
- C. Conduct tests of the temporary system.

On 10 July 1970, Contract NASW-2014 was modified to include the complete design, development, and fabrication of one optical-mechanical unit of the extended-range transmitter. After receipt of NASA's concurrence, a subcontract with Group 128, Inc., of Waltham, Massachusetts, was placed for the design and modification of the ERT. The ERT is scheduled to be delivered on 2 November 1970.

5. PROGRESS ON TASKS SUPPORTED
BY CONTRACT NASW-2014

During the interval covered by this report, tasks A and B were completed. Work on task C began during this period and will continue through the next reporting period if, as requested in SAO Proposal P 239-4-70 dated April 1970, funds are made available. Both the laser and the optical system have been installed in a two-room building specially built for this program. The laser operates under field conditions. Rental from the American Optical Corporation will start 1 August. During acceptance tests at full energy, the reflecting surface of the dichroic mirror was damaged by the high energy density of the beam. American Optical Corporation replaced the mirror with one having a harder coating. The new mirror appears to be satisfactory.

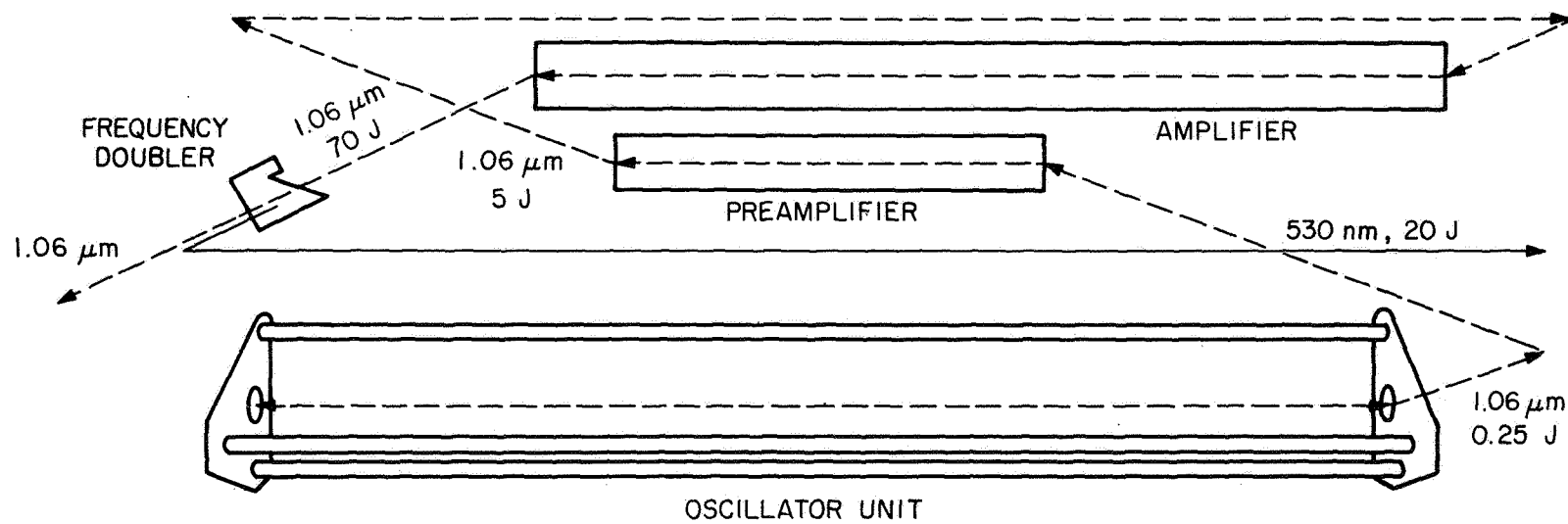
6. DESCRIPTION OF THE TEMPORARY LASER SYSTEM

The high radiance of the glass laser, which makes it particularly suitable for extended ranging, influenced the design of the optical system. The most noticeable difference from a ruby-laser system is the smaller size of the transmitting optics. The reason that smaller optics can be used is that the divergence of the beam as it leaves the laser is 5 to 20 times less than that of a ruby laser. The small size of the transmitter and receiver will be apparent in the figures, photographs, and discussions to follow. This reduction in size introduces high energy densities, which the various components must withstand. The required high pointing accuracy introduces other exacting requirements into the mechanical design. For the tracking of close satellites the *coudé* errors in the transmitting telescope should not exceed 1 arcmin.

6.1 The Neodymium-Glass Laser

Figure 1 is a top view of the laser with an accompanying ray diagram. The laser oscillator is designed to operate in a single transverse mode, which produces an essentially diffraction-limited beam at 1.06 μm . The preamplifier and amplifier increase the energy 280 times. At the output of the amplifier the beamspread is about two times the diffraction limit. This radiation is doubled in frequency, and about one-third of the infrared energy is converted to 530 nm. The final output in the green is 20 J (with 10 J between half-power points) and the beamspread is about four times the diffraction limit.

Figures 2 to 4 show and label components of the laser not readily visible in Figure 1. Figure 5 shows how the laser is mounted on a granite block and concrete pier. It also depicts the plastic cover and the mounting cylinders for the transmitting optics and the autocollimator. Figure 6 shows the insulated cover in place along with the cooling unit, controls, and meters that must be located near the laser. The large capacitor units and other



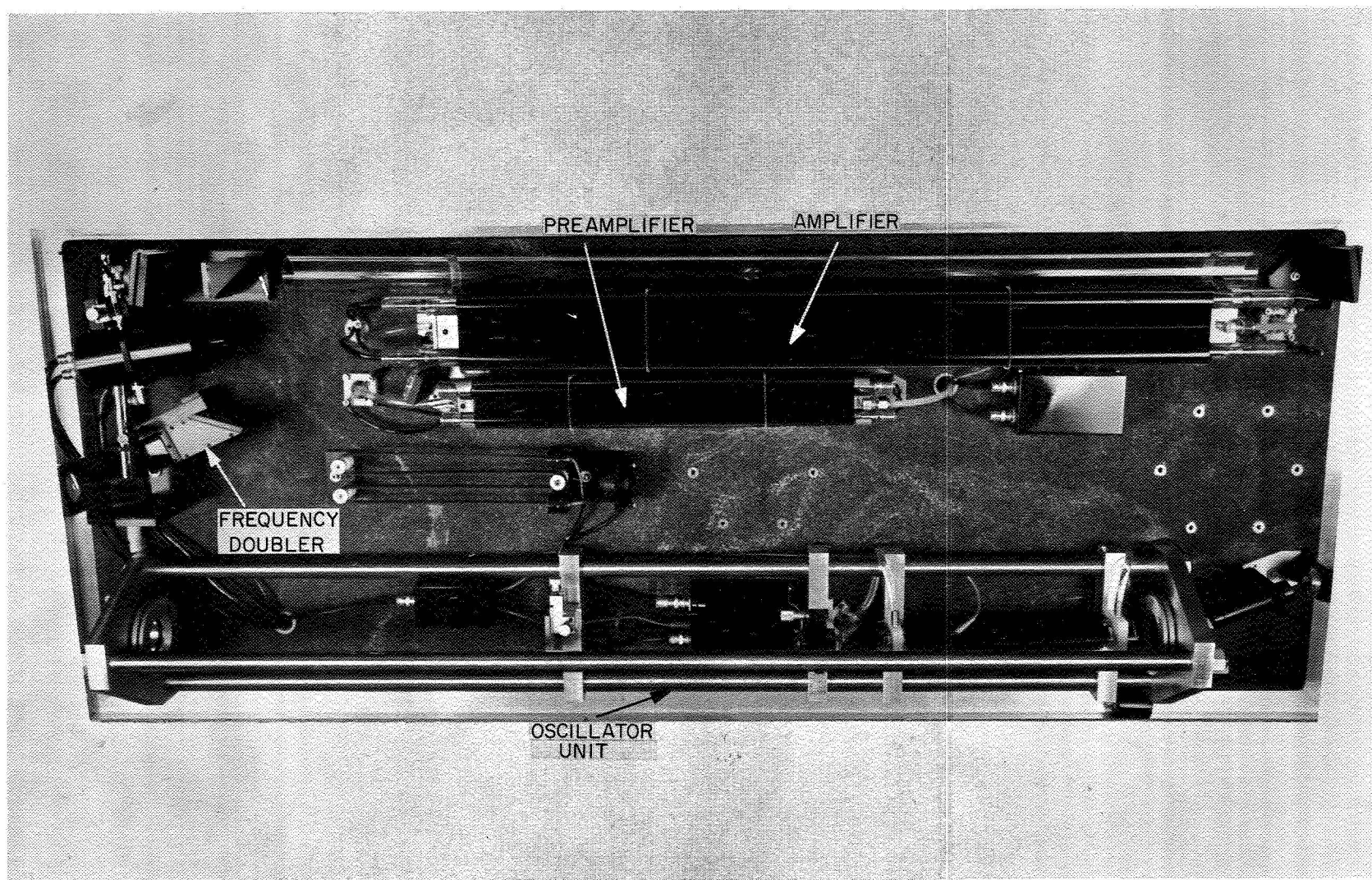


Fig. 1. Photograph and ray diagram of the American-optical glass laser.

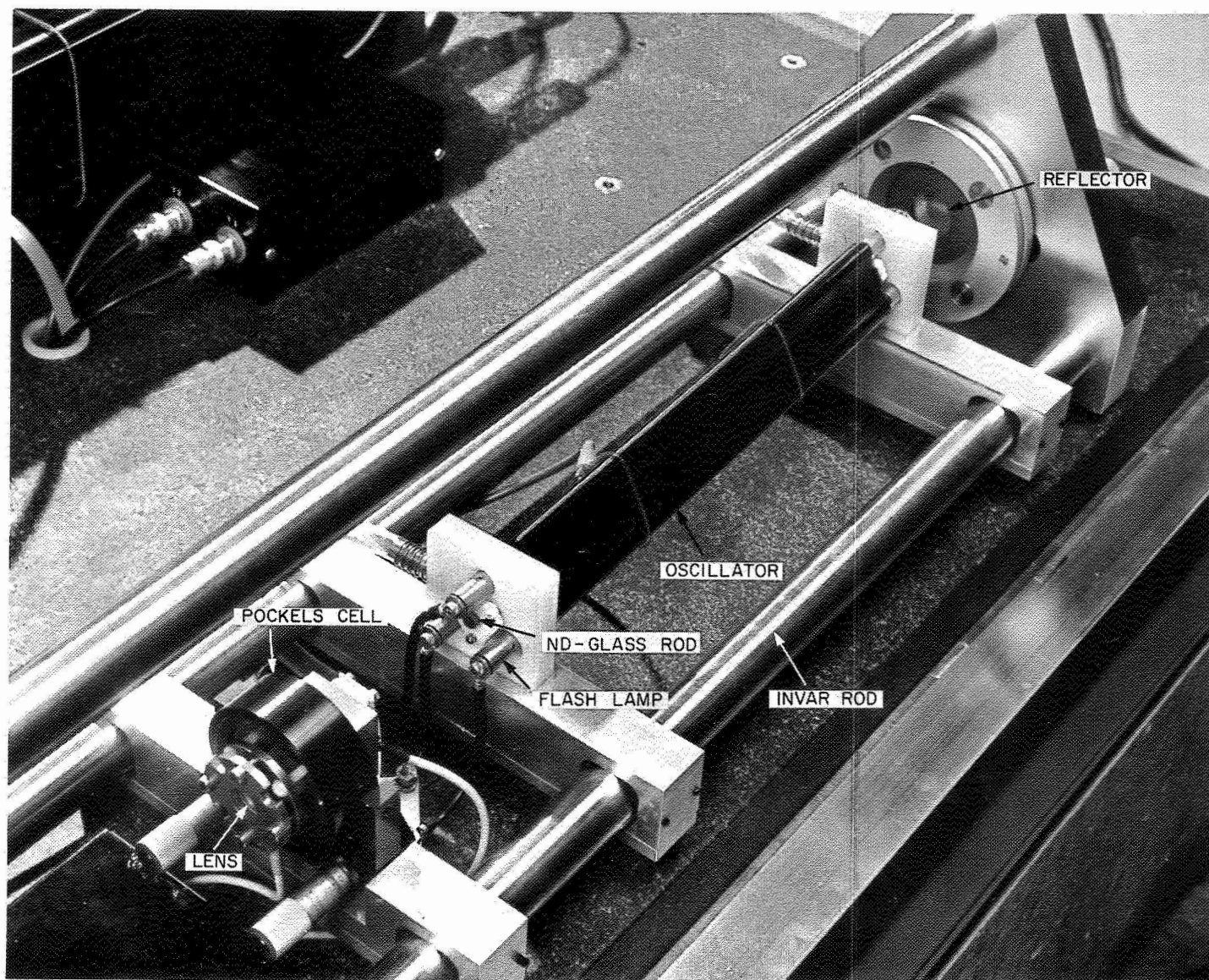


Fig. 2. Detail of oscillator unit.

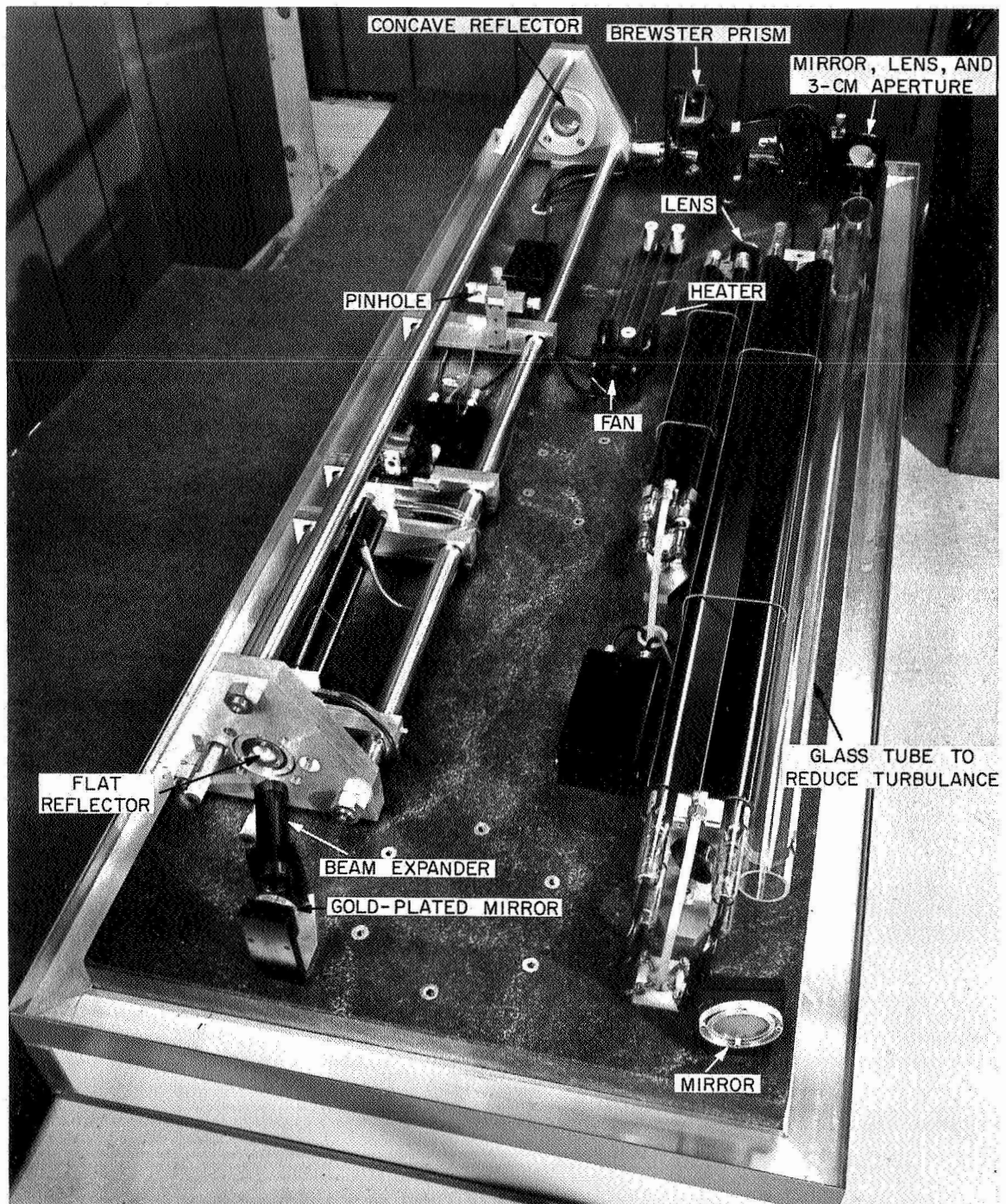


Fig. 3. View looking into output laser beam.



Fig. 4. Detail in vicinity of frequency doubler.

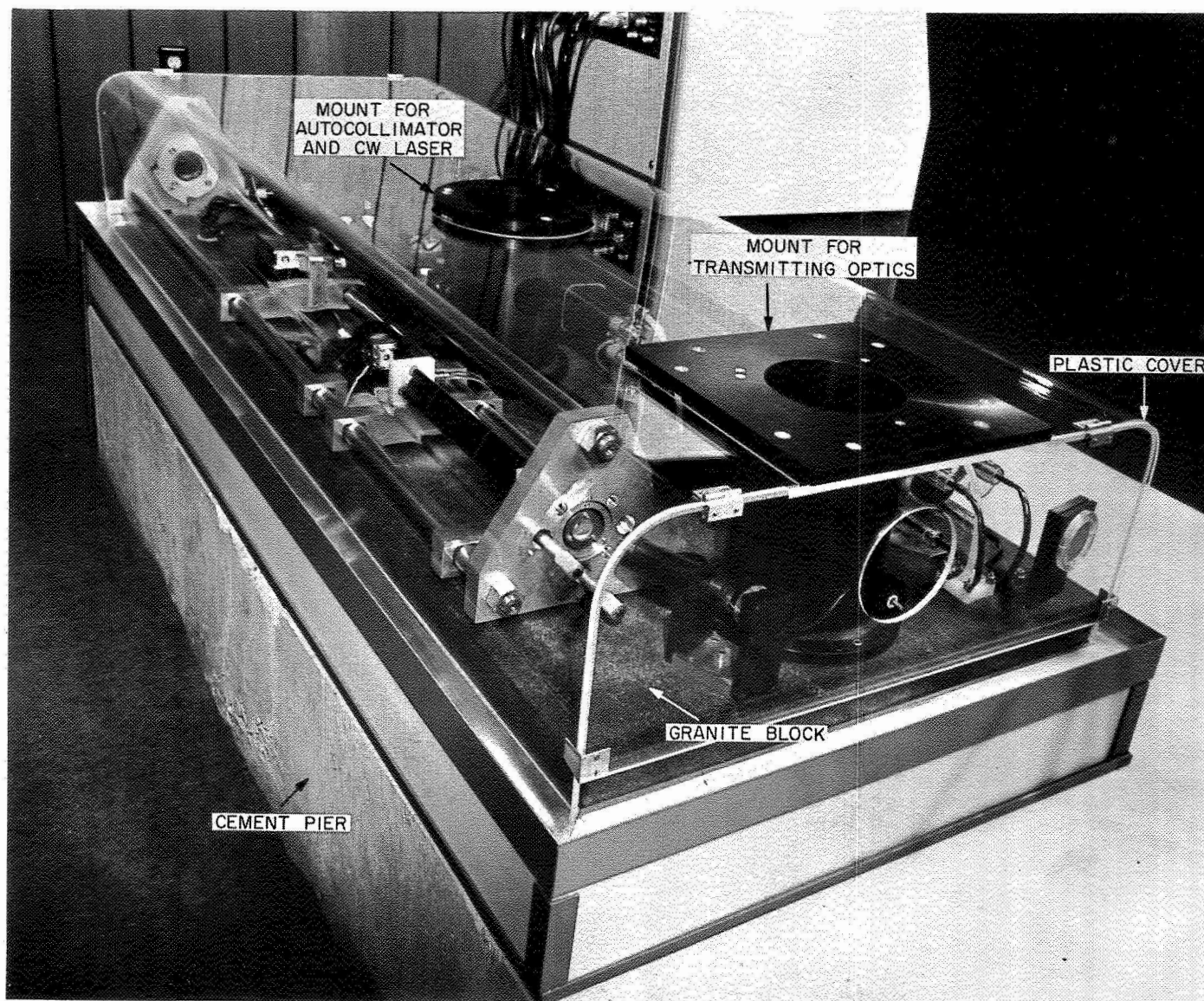


Fig. 5. View showing plastic cover and mounting for the transmitting optics and the autocollimator.



Fig. 6. Laser covered and in place on concrete pier.

controls are in an adjoining room. The laser is protected by its mounting and covers from dust, temperature variations, and vibrations — all of which can affect its performance.

The active part of the oscillator is a neodymium-doped glass rod 1/4 inch in diameter and 12 inches long. The ends of the glass rod have 5° bevels to reduce reflections that might interfere with those from the mirrors at the ends of the invar rods. The three flashtubes provide an input energy of 1 kJ. Their voltage is 2.8 kV. The Pockels-cell Q-switch produces the 20-ns pulse for ranging applications. A lens next to the Pockels cell and the concave reflector at the left-hand extremity of the oscillator structure focus the stimulated radiation through a pinhole 0.0105 inch in diameter. This pinhole is important in the achievement of minimum beams spread. The infrared beam leaves the oscillator through the Brewster prism that also acts as a 4% reflecting mirror for the laser's resonant cavity. Then it goes through a beam expander and is reflected by a gold-plated mirror to the preamplifier.

The preamplifier consists of a neodymium-glass rod with Brewster ends. It is 1/2 inch in diameter and 21 inches long. Four flashlamps supply a pump energy of 6 kJ. The lamp voltage is 4.3 kV. The output beam is reflected by a crown glass, antireflection-coated mirror. It is expanded five times and passed through a 3-cm aperture placed at an angle to the beam. This aperture gives the beam the 3 cm × 2 cm elliptical cross section appropriate to the Brewster cut on the final amplifier. The aperture also eliminates the "gaussian" wings of the single-mode beam pattern and produces a more nearly Fraunhofer beam. The elliptical beam traverses the length of the unit through a glass tube (used to reduce possible air turbulence) and enters the final amplifier from the right.

The glass rod in the final amplifier is 1 1/2 inches in diameter and 39 inches long. It is pumped by four flashlamps providing 35 kJ when pulsed at 4.3 kV. The output beam, now about two times the diffraction limit, enters the KDP doubler crystal and emerges as two parallel beams one at 530 nm and one at 1.06 μm . A dichroic mirror reflects the 530-nm beam

and passes the 1.06 μm beam, which enters a piece of absorbing material. The reflected, elliptically-shaped beam is passed through a Brewster prism, where it regains a circular cross section, and on to the transmitting optics.

The laser output is monitored by a detector having four solid-state diodes: a Tropol diode for the pulse shape at 530 nm, and three others for the energy at 1.06 μm and 530 nm and the power at 530 nm.

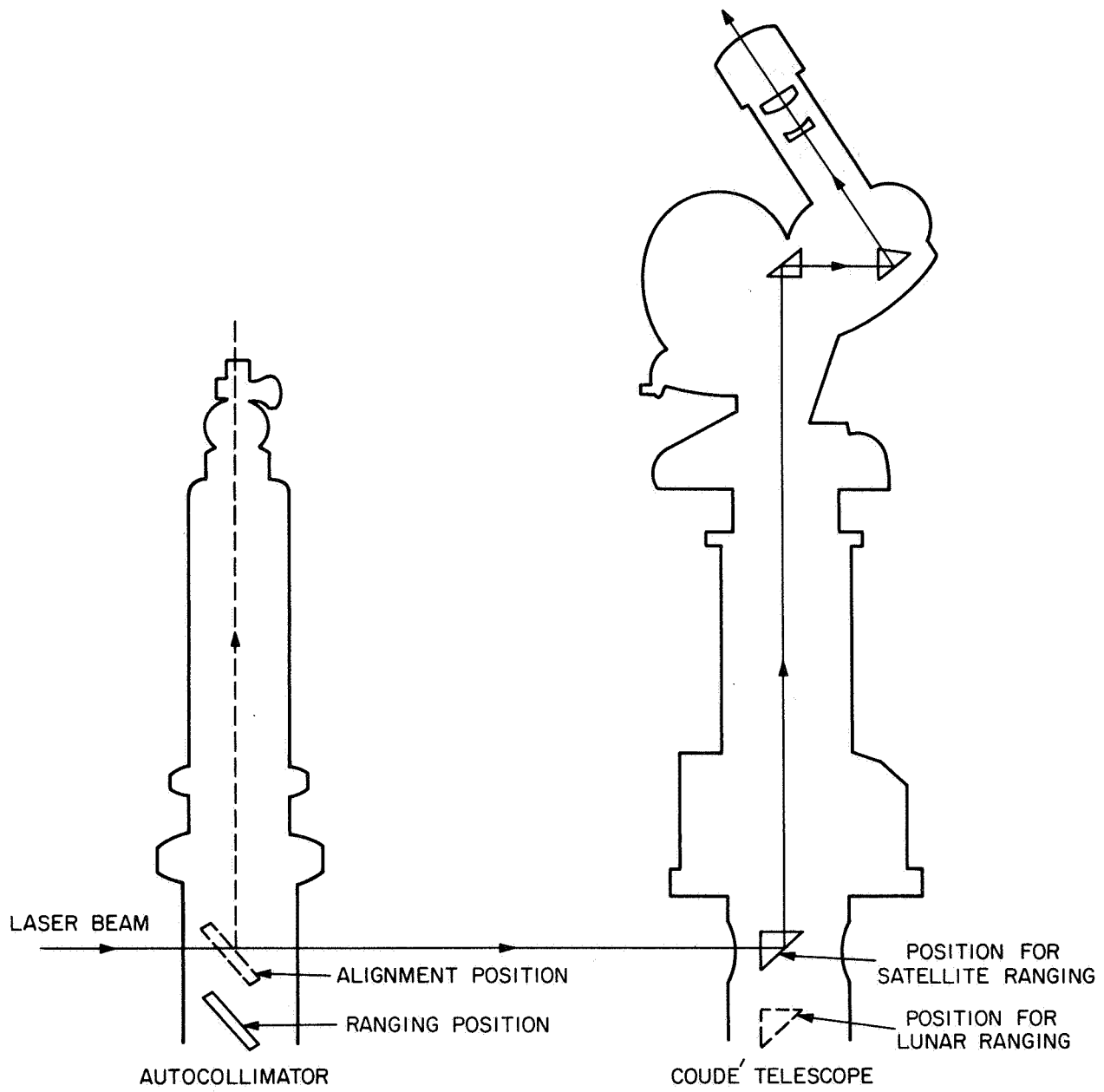
The heating unit and fan are designed to keep the unit at a constant temperature of about 100 F regardless of fluctuations in the ambient temperature of the building. The laser rods are cooled by circulating a 10% aqueous solution of sodium nitrite.

The flashlamp energy comes from capacitor banks housed in six cabinets. They are in an adjacent room. The capacities are the following:

Oscillator	240 μf
Preamplifier	640 μf
Amplifier	3,840 μf .

6.2 The Coudé Transmitter

Figure 7 shows the coudé transmitting telescope and the autocollimator that will be used to align the laser beam and the three prisms. Both units are set on the columns that were shown in the photographs of the laser unit. The autocollimator will be replaced by a University Laboratories Model LH341 helium-neon laser during certain phases of the alignment procedure. The prism at the base of the telescope (see Fig. 8) can be lowered to a position below the laser beam when lunar ranging is attempted with the extended-range transmitting unit. The coudé telescope bends the beam to the predicted satellite direction set by the azimuth and elevation handwheels. The beam divergence as it leaves the laser is only about 0.5 arcmin. It is necessary to increase this divergence to allow for errors in satellite predictions. Hence, the effect of this telescope is opposite to that of the extended-range transmitting optics, which will narrow the beam to 4 arcsec. By turning the



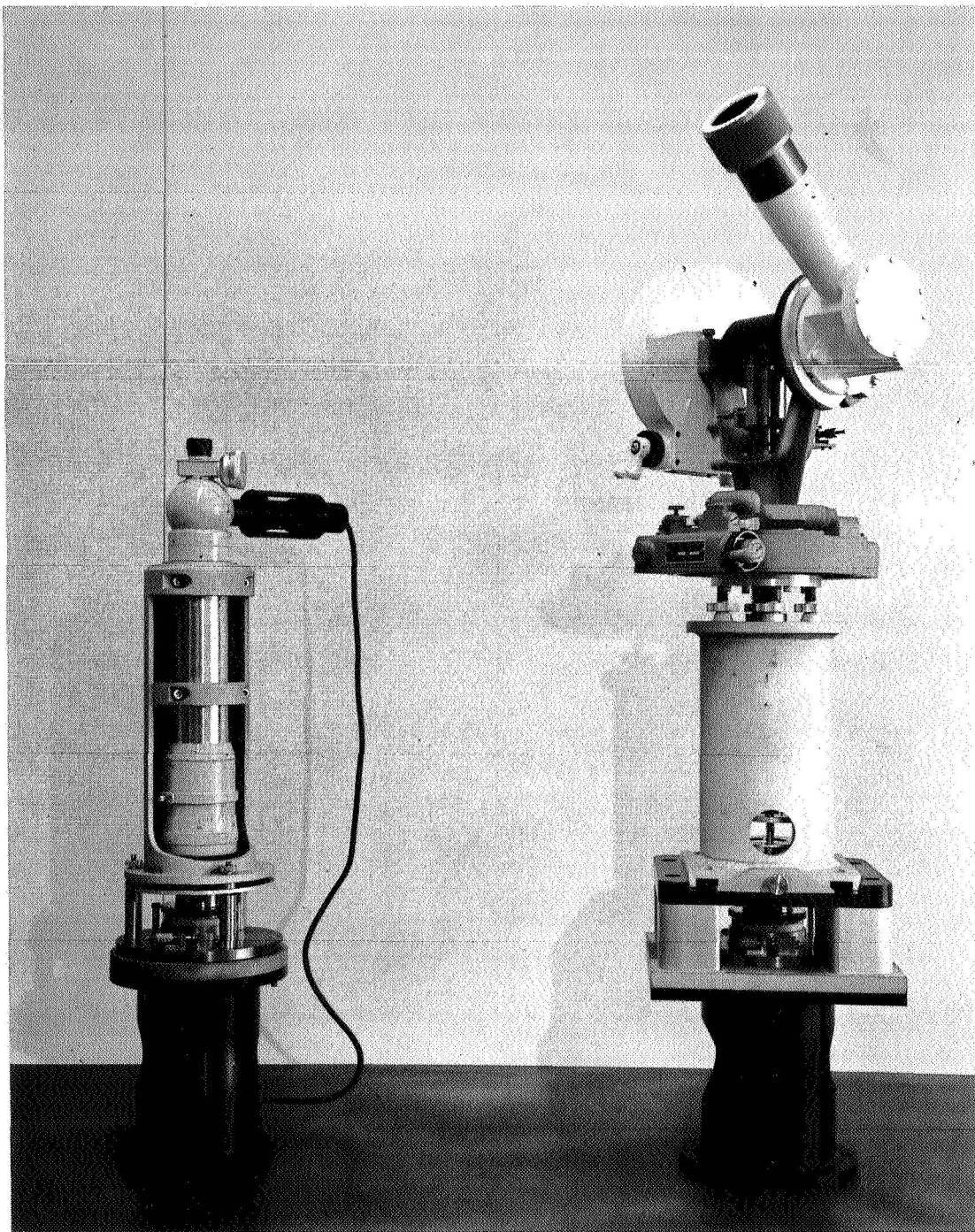


Fig. 7. Photograph and ray diagram of transmitting and alignment optics.

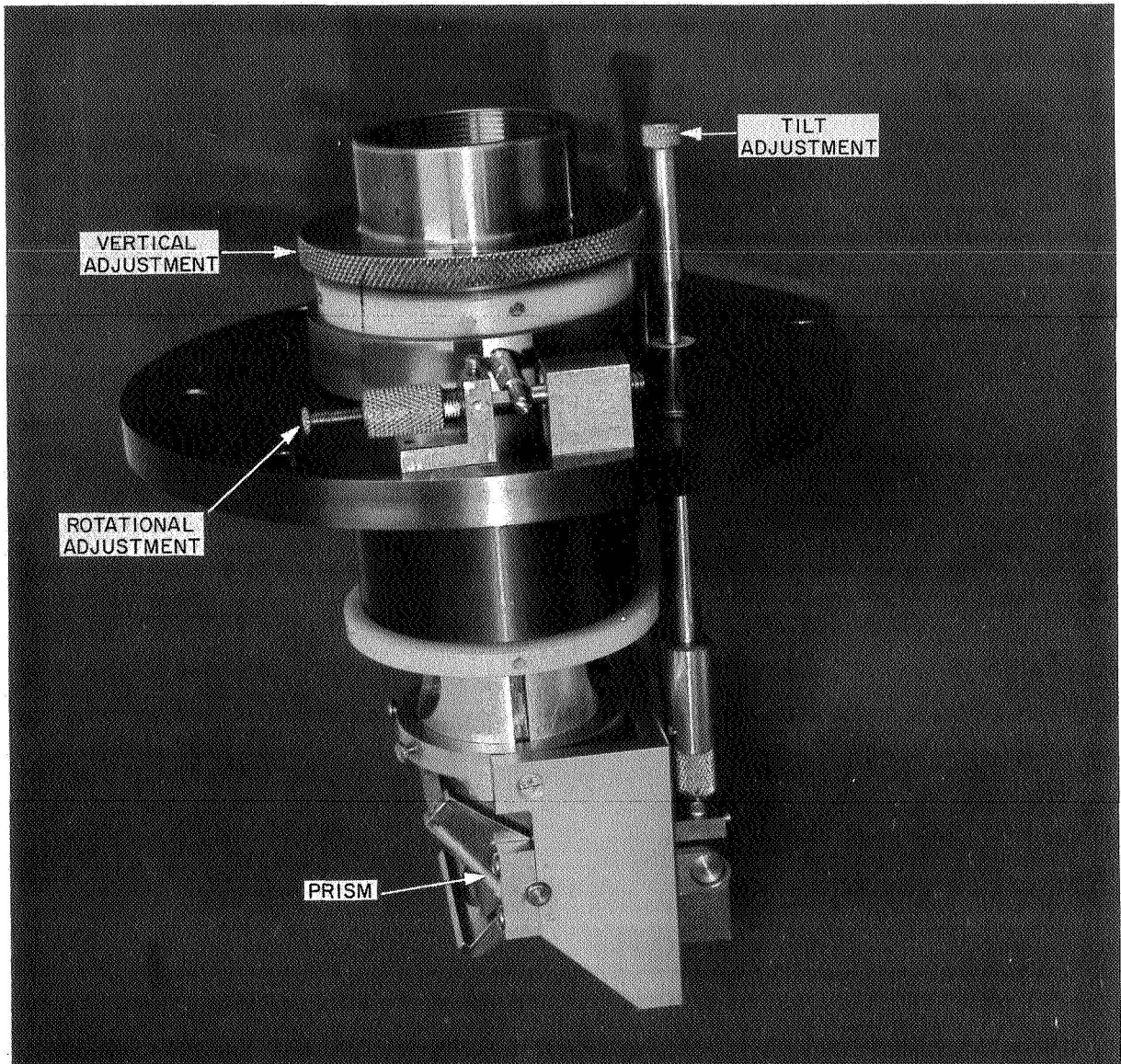


Fig. 8. Adjustments for prism at entrance of laser beam.

knurled end of the telescope, the beam divergence can be adjusted from about 2 arcmin to 20 arcmin by decreasing the separation of the convex and concave lenses. The amount of this decrease is 2.8 cm.

The adjustment mechanism for the entrance prism is shown in Figure 8. Differential screws are used for precision. The mirror below the auto-collimator has a similar mechanism and the remaining two prisms in the telescope can also be precisely adjusted.

Figures 9 and 10 show the input prism arranged, respectively, for satellite and lunar ranging. Figure 11 shows a partial assembly of the transmitting telescope. The differential screws are visible for the adjustment of the prism on the azimuth axis. Figure 12 shows the barrel of the transmitting telescope along with an attached mirror that is used for alignment. This mirror will focus the laser beam to a point on an exposed Polaroid film. The beam will mark a small spot that will be used to define the direction of the beam. There are several other devices also used for alignment, but these are not shown in the figures.

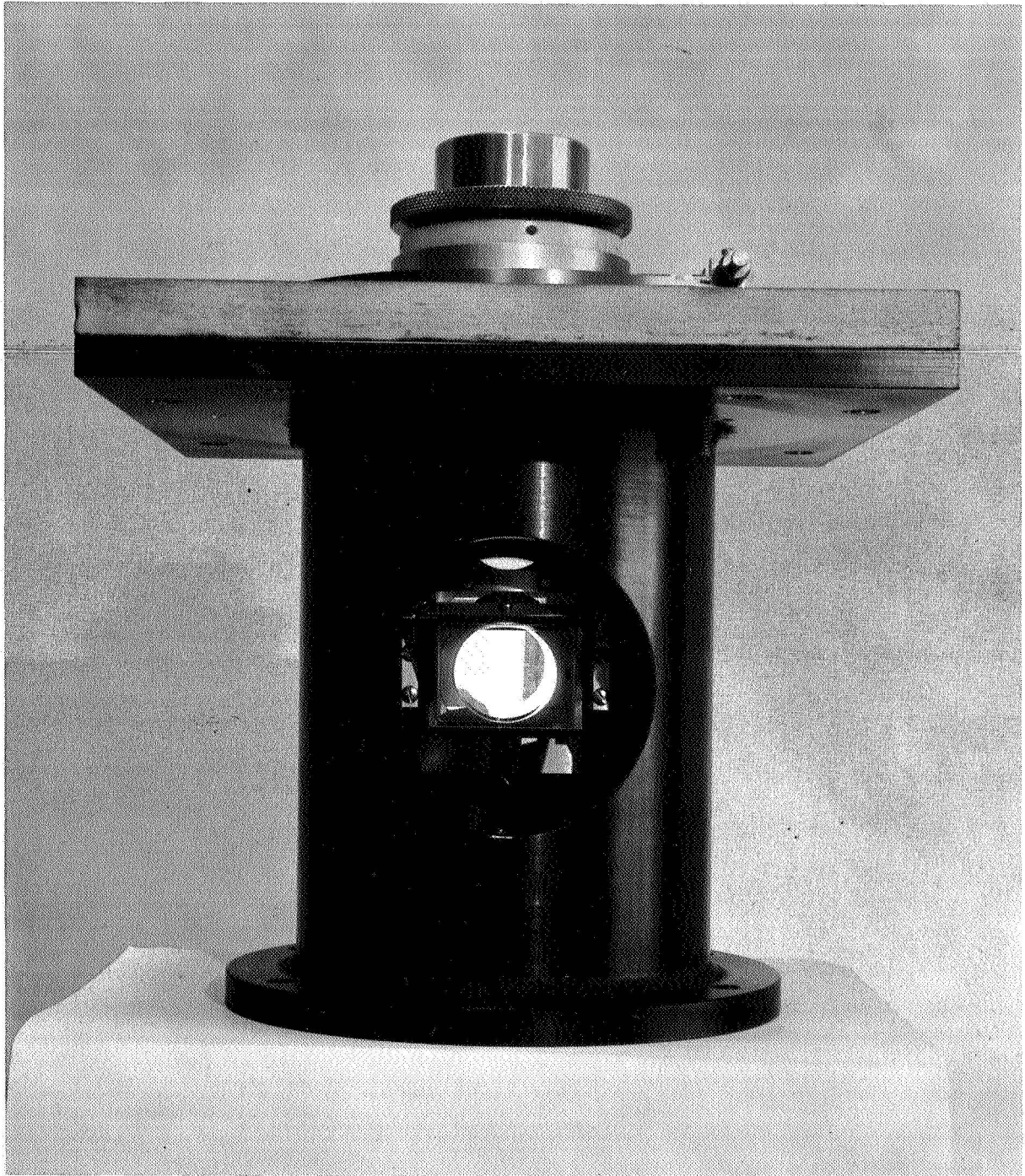


Fig. 9. Prism in place for satellite ranging.

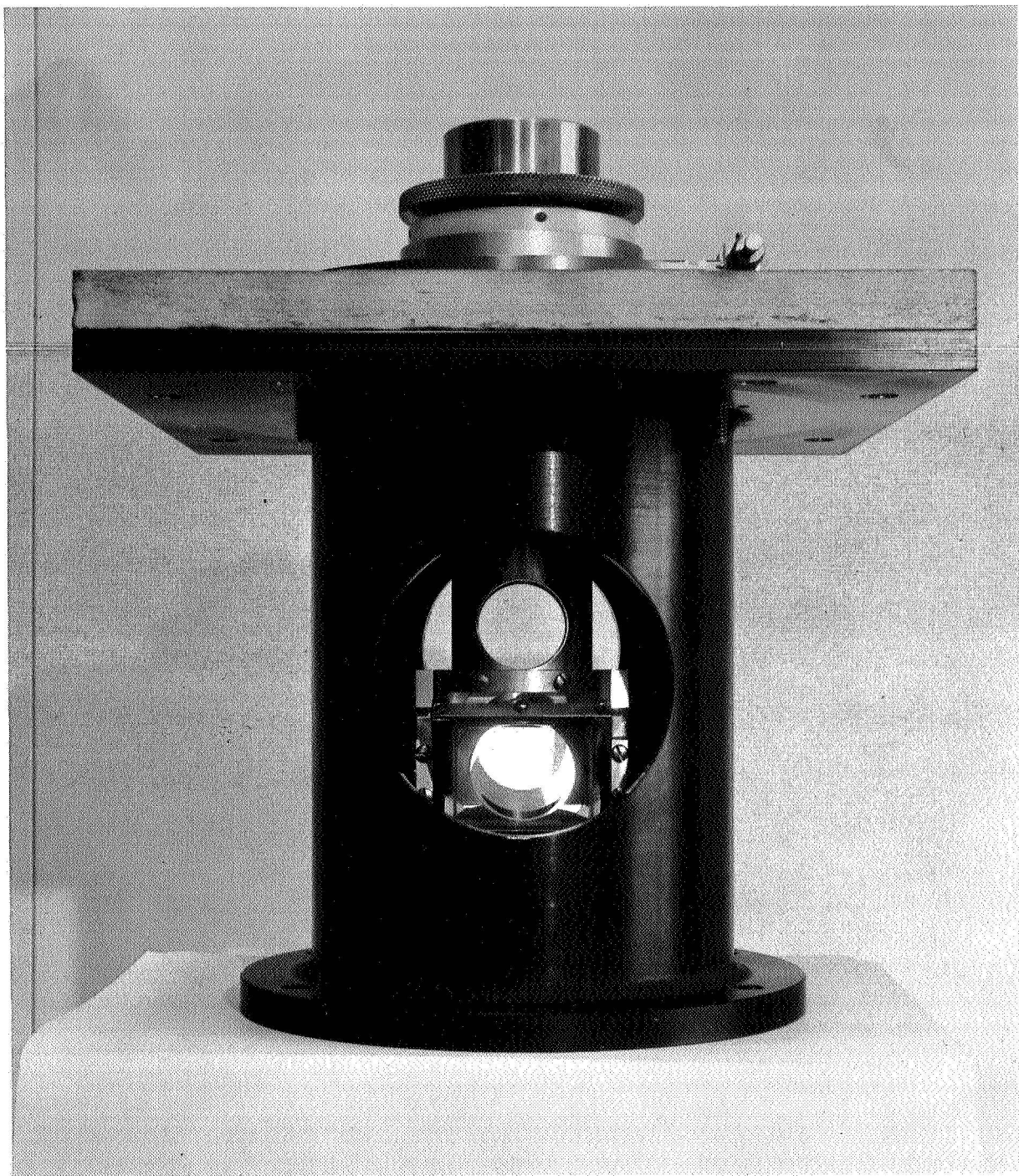


Fig. 10. Prism lowered for lunar ranging.

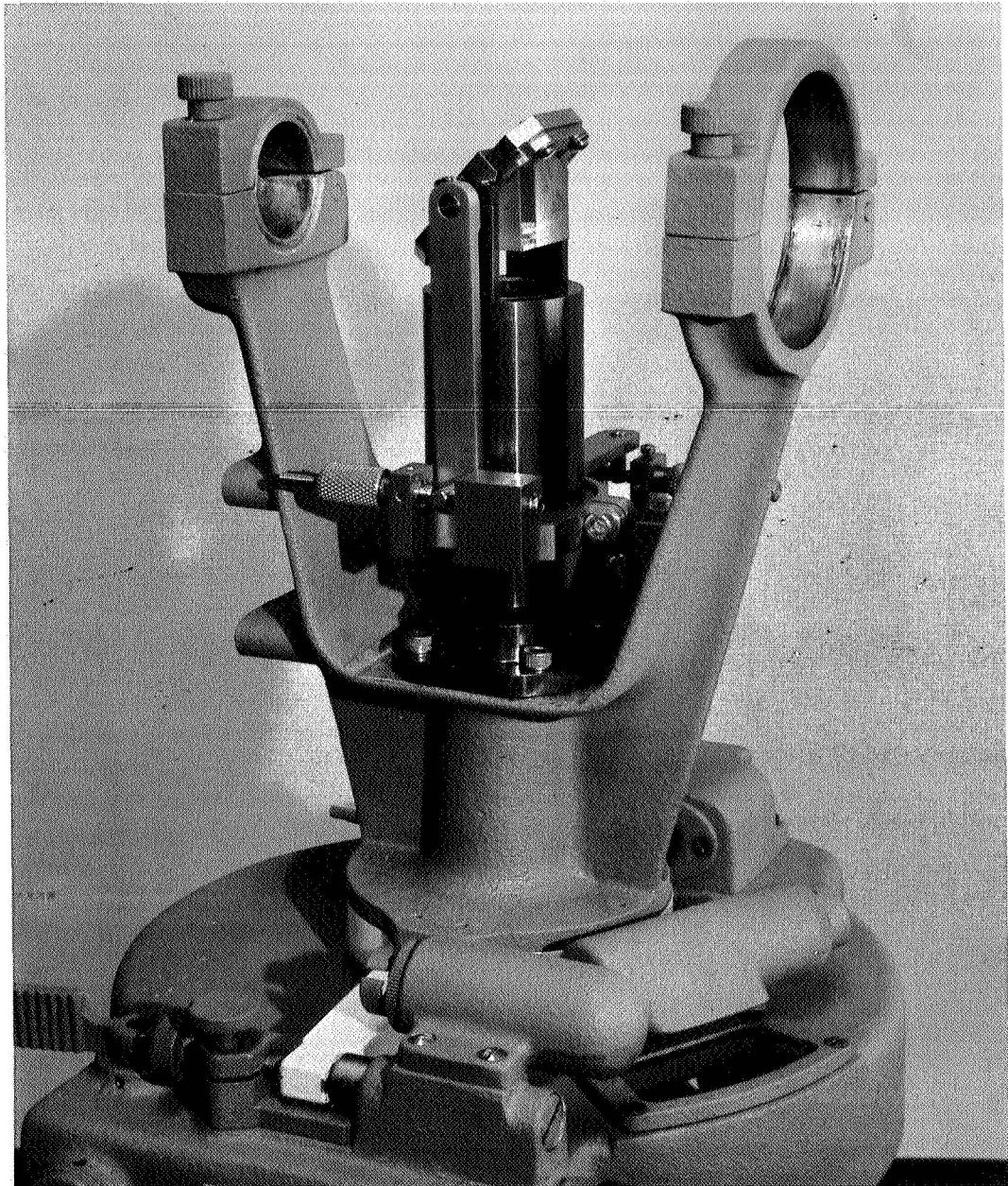


Fig. 11. Partial assembly of transmitting telescope showing

- Indicator for azimuth setting
- Prism on azimuth axis with adjusting mechanism
- Yoke for elevation axle.

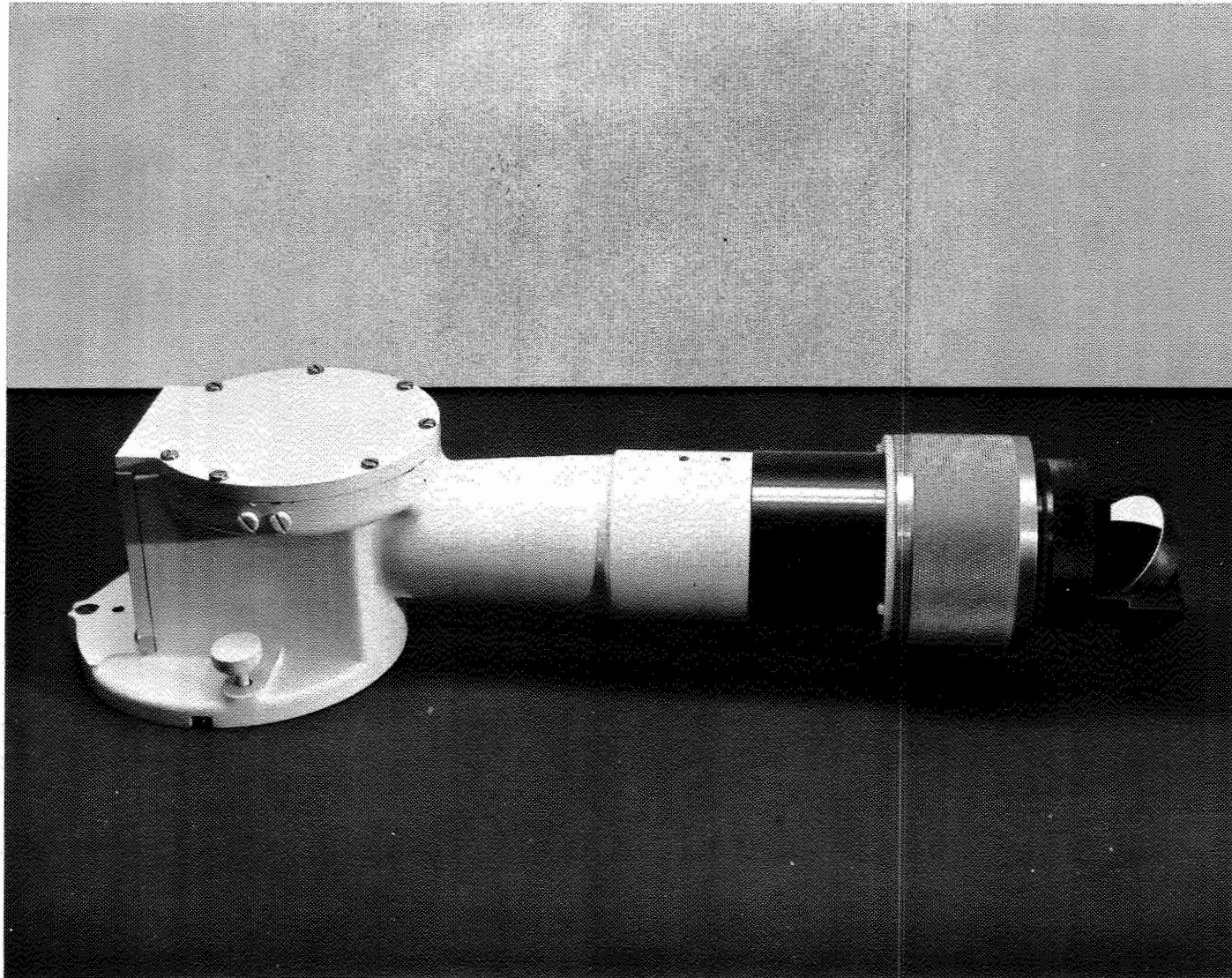


Fig. 12. Transmitting telescope with alignment mirror attached.

7. ANALYSIS

To date, no major technical problems have occurred in the design and fabrication of the system.